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SSME ENVIRONMENT
DATABASE DEVELOPMENT

FINAL REPORT

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TABLE OF CONTENTS

SECTION	PAGE
1.0 INTRODUCTION	1
2.0 DATABASE DESIGN	2
2.1 OVERVIEW	2
2.2 USER INTERFACE	4
2.3 DATA RETRIEVAL EXAMPLE	7
3.0 DATA ENTRY	14
4.0 DATA ANALYSIS	17
4.1 SSME DATA ANALYSIS METHODS	17
4.2 GEOMETRY CONVENTIONS	19
5.0 REFERENCES	21

1.0 INTRODUCTION

The internal environment of the Space Shuttle Main Engine (SSME) is being determined from hot firings of prototype engines and from model tests using either air or water as the test fluid. The objectives of this contract were : 1) to develop a database system to facilitate management and analysis of test measurements and results; 2) to enter available data into the database; and 3) to analyze available data to establish conventions and procedures to provide consistency in data normalization and configuration geometry references.

The database system was developed and installed on the DEC VAX 11/750 computer system at the NASA/MSFC Aerophysics Division Experimental Facility. The file structures and access routines provide rapid access to data stored in binary form to minimize storage requirements. It provides storage of "measured data" as received from the data acquisition section and "engineering data" which has been reduced and relased for access by analysis users. The system is fully operational in the initial state, but it is planned that enhancements will be added in the future to simplify interaction, improve security, and add geometric displays.

In the data entry task, data from MSFC Water Flow Facility (WFF) tests of the SSME hot-gas manifold were entered into the database. Data from three tests were entered as "measured data", and data of one of these tests was reduced and converted to "engineering data" for access by analysis users.

In the data analysis task, data from air and water tests were analyzed to evaluate two areas: criteria for measuring losses in the SSME hot-gas manifold flow and similarity requirements for SSME testing. In addition, a document of recommended geometric description standards and transformation procedures was prepared and submitted in draft form for comments.

The remaining sections of this report summarize the results in each of the three areas of the work, and provide references of publications with further details.

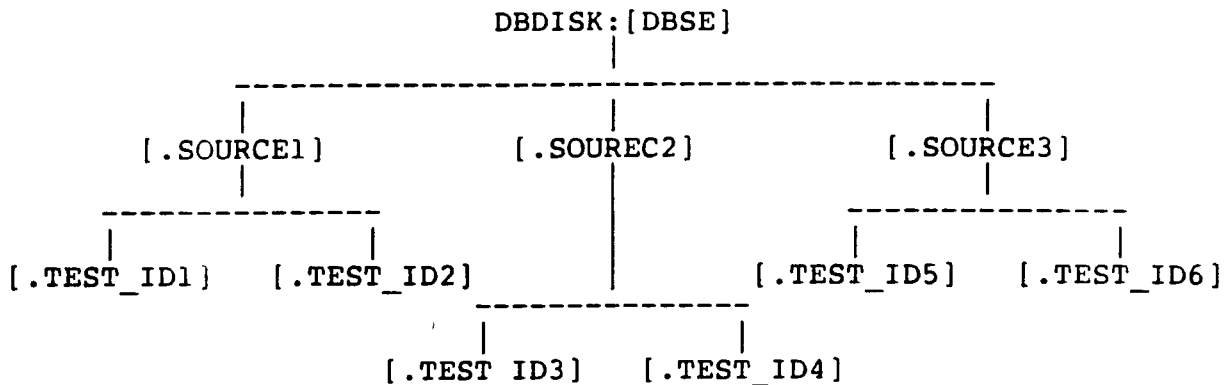
2.0 DATABASE DESIGN

2.1 OVERVIEW

The AFAS Database System was developed to provide the basic structure of a comprehensive database system for the MSFC Structures and Dynamics Laboratory Aerophysics Division. The system is intended to handle all of the data obtained from the Aerophysics Division Test Facilities as well as data from other sources. The system has been written for the DEC VAX family of computers in FORTRAN-77, and it utilizes the VMS indexed file system and screen management (SMG) routines.

The initial implementation of the system has the ability to store and retrieve data, but it has been planned to allow future enhancements to include geometry transformations, geometric display, and multiple input formats. The current system defines three user levels: the database manager who has overall system control, the test engineer who is responsible for the entry and validation of the data, and the analysis user who uses the data. Two types of test data are maintained for these users: measured data with filenames using an M suffix, and engineering data with filenames using an E suffix. The "measured files" can only be accessed by the database manager and the test engineer. After evaluation and analysis, the valid portion of the measured data along with averaged data and other significant, derived parameters are transferred to the "engineering files" for analysis users. The product of the user's work will be maintained in the user's directory by the user, but future enhancements could include maintenance of useful test comparisons and analytical results in the database system.

The database directory structure has a root level directory with subdirectories representing each data source (facility). Each source directory contains directories corresponding to specific test identification nomenclature. The directory tree structure is illustrated below.



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At the highest directory level the system provides a test index file summarizing all tests available on the system. Each test directory contains a number of informational files and possibly a geometry file, but the three basic files involved in the stored data structure are: the VALUE file, the LABEL file, and the SET file.

The data VALUE file stores test data as a matrix which can be visualized as columns representing measurements (or test parameters), and rows representing test conditions. The data values are stored in an indexed file with records representing columns of the table. The data label describing the measurement is the record key, and the data value for a desired test condition is located by a common offset in all records.

The LABEL file contains a record for each data label. Information in the record defines characteristics of the measured data values corresponding to the label. The purpose of this record is to provide the system and the user with information about the measurement. The structure of the label file record is defined by a parameter file. This allows the database manager to specify field names and field lengths to be used for measurement description on a particular test. The record must include the name of the data label (the key field), and two data descriptors with required field names -- the type of the values to be stored under this label (DATATYPE= I[nTEGER], R[eal], or C[haracter]), and the field length (FLDLN=data value length in bytes). Other optional fields might include: a short descriptor for the measurement, units for the measurement, or geometry values locating the measurement. As the database functions are expanded to include additional automated access to the data label record, the field names for certain label descriptive data will need to be standardized. A standard geometric description is currently being developed (Ref. 1).

The SET file contains groupings of data labels which are desired for applications such as plotting of geometrically related data and data input sequences. This is an indexed file using the set name as a key. Each record provides fields for the data label names in the set. Fields are also provided for defining plotting variables (e.g. THETA) and values of the variable for each data label (e.g. 0, 45, 90, ...).

A user accesses data in the VALUE file by entering a sequence of data labels of interest. A data range may be entered for each label, but if no range is entered, the system will limit the data to the range of run conditions defined by previous selections. The initial default value for the range includes all the run conditions on file. When a range is specified for a label, the data record for which the label is a key is searched to determine the offsets in the data record of all values falling within the specified range. This list of offsets is then maintained as pointers to data positions in subsequent record accesses, and the list is reduced as required for subsequent range entries. The user may also enter a set name rather than a

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data label. In this case, the system will select all data for the labels defined for the set in the set file, and the currently defined range will be used.

When the user has selected all desired data, the system prepares either a printed report of the data selected or output files suitable for input to the BBN RS/1 data analysis system. The three output files are: (1) data labels with corresponding data values for the range selected, (2) plotting parameters for any sets selected, and (3) data label description records from the LABEL file. The plotting parameter set records are offset, so they can be combined by an RS/1 procedure which will align the plotting parameters at the bottom of columns in a table containing the corresponding data label and data values.

The following subsections will describe the functions in the three user interfaces and illustrate the data retrieval task with an example. Further details of the database operation are available in the three user's manuals (Refs. 2-4).

2.2 USER INTERFACE

The AFAS Database System uses a menu-driven interface to a network of data files and information files that can provide data on any test in the database. Database access is divided into three levels: database manager, test engineer, and analysis user. Functions for each of these levels are outlined in Table 2.1. When a user views the top level menu (Table 2.2), it will only display the routines which may be accessed in accordance with the user's privilege.

The tasks exclusive to the database manager concern maintaining the directory structure, maintaining the file describing available tests, and originating parameter files governing the LABEL file record format for each test. The test engineer tasks include all routines required to enter the measured data, control valid data selection, reduce the data, and move the measured data to the engineering data files for the analysis user. The analysis user cannot affect any of the database files. One can only access the engineering data for analysis, and the results are maintained in the user's directory.

TABLE 2.1
DATABASE FUNCTION SUMMARY

DB MANAGER FUNCTIONS

- o Maintain the index file for tests available on the system.
- o Create the parameter files defining LABEL file records for each test.
- o Install text files for reports.

TEST ENGINEER FUNCTIONS

- o Create the LABEL file of unique labels with descriptive information.
- o Create the SET file for plotting groups and input formats.
- o Create the geometry file if transformations are desired.
- o Enter the measured data into the VALUE file.
- o Prepare measured data for movement to the engineering files.
- o Move measured data to the engineering files.
- o Enter BBN RS/1 files of reduced data into the engineering files.

ANALYSIS USER FUNCTIONS

- o Scroll through test index file to select a test of interest.
- o Scroll through LABEL or SET files to select measurements.
- o Select data ranges desired.
- o Select output form - report or RS/1 files.

TABLE 2.2

MAIN MENU FOR THE ANALYSIS USER

To gain access to the AFAS Database System enter "DBS". This will display the database option menu. The menu options will vary according to the privilege assigned to the user gaining access. The top level menu contains the following options.

- (R) - Test Data Load/Retrieval
- (A) - View Abstract
- (P) - View Pre-Test Report
- (T) - View Test-Schedule Report
- (F) - View Final Test Report
- (E) - View Data File
- (W) - Define Default Work Disk
- (Q) - Quit/Exit

Option "R" executes the Test Data Retrieval Tasks which enable a user to create RS/1 compatible data files from the test data in the database.

Option "A" displays the Abstract for a test.

Option "P" displays the Pre-Test Report for a test.

Option "T" displays the Test-Schedule Report for a test.

Option "F" displays the Final Report for a test.

Option "E" executes the Test Data Editor which allows read access the VALUE file.

Option "W" defines the logical DBDISK which is used for the default data storage disk.

Option "Q" exits the AFAS Database system and returns control to user mode.

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2.3 DATA RETRIEVAL EXAMPLE

The operation of the system in retrieving data for a test is best explained through the use of a simple example. The example uses the portions of the LABEL, SET, and VALUE files shown in Table 2.3.

In this example the user wants the following information:

RUN	For all accessed data.
RERUN	For all accessed data.
FLOW	For rates of 450 to 455 CFS only.
PLANE H	All pressures and plotting values.
LINE A	All pressures and plotting values.

STEP 1: ACCESS DATA RETRIEVAL TASKS

Select option "R" from the main menu (Table 2.2). The user is asked for program initialization information with the prompt:

- (B) - Begin New Session
- (R) - Resume Previous Session
- (?) - Help
- CNTRL/K - Exit Data Retrieval Program

This enables the user to create a new session log or resume a previous session log. If a "Begin New Session" is selected, the system will prompt for the test source (facility) and test identification. Otherwise, the test is identified by the previous session log file.

NEW SESSION

If a new session log is created, the user is requested to enter the desired SOURCE. The user has the option of either viewing a list of valid SOURCE names for selection or entering the SOURCE directly. The options appear as shown below.

- (A) - View Sources
- (B) - Enter Source
- (?) - HELP
- CNTRL/K - Return to Main Menu #1

TABLE 2.3

FILE PORTIONS FOR USER ACCESS EXAMPLE

LABEL FILE :

LABEL NAME	DATA TYPE	FIELD LENGTH	UNITS	DESCRIPTOR
RUN	C	12		PRIMARY TEST CONDITION IDENTIFIER
RERUN	C	12		SECONDARY TEST CONDITION IDENTIFIER
FLOW	R	4	CFS	SYSTEM FLOW RATE
P1	R	4	PSIA	STATIC - PLANE H 0 DEG / LINE A X/L=0
P2	R	4	PSIA	STATIC - PLANE H 60 DEG
P3	R	4	PSIA	STATIC - PLANE H 120 DEG
P4	R	4	PSIA	STATIC - PLANE H 180 DEG
P5	R	4	PSIA	STATIC - PLANE H 240 DEG
P6	R	4	PSIA	STATIC - PLANE H 300 DEG
P11	R	4	PSIA	STATIC - LINE A X/L=0.5
P21	R	4	PSIA	STATIC - LINE A X/L=1.0

SET FILE :

SET NAME	DEPENDENT PARAMETER	LABEL/DEP	VALUE PAIRS
PLANE H	THETA	P1 0. P2 60. P3 120. P4 180. P5 240. P6 300.	
LINE A	X/L	P1 0. P11 0.5 P21 1.0	

VALUE FILE :

RUN	98	99	100	100	101	102	102	102	102	103	104
RERUN	1	1	1	2	1	1	2	3	4	1	1
FLOW	445.	444.	450.	451.	450.	452.	451.	455.	450.	460.	456.
P1	14.4	14.3	14.6	14.7	14.5	14.4	14.7	14.6	14.5	14.9	14.8
P2	14.6	14.4	14.8	14.9	14.8	14.9	14.9	15.0	14.9	15.1	15.1
P3	14.7	14.6	15.0	14.9	14.9	15.1	15.0	15.1	15.1	15.3	15.2
P4	14.9	14.9	15.1	15.0	15.0	15.0	15.0	15.0	15.1	15.2	15.2
P5	15.2	15.1	15.3	15.2	15.3	14.9	14.9	14.9	14.8	15.0	15.0
P6	14.8	14.8	15.0	14.8	14.9	14.8	15.0	14.8	14.9	15.1	15.1
P11	13.7	13.6	14.0	13.9	14.0	13.8	14.1	14.0	14.2	14.3	14.3
P21	13.1	13.1	13.5	13.4	13.5	13.3	13.4	13.2	13.6	13.8	13.7

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Next, the user is requested to enter the TEST ID. The user has the option of either viewing a list of valid TEST IDs for the SOURCE or entering the TEST ID directly. The options appear as shown below.

- (A) - View TEST IDs
- (B) - Enter TEST ID
- (?) - HELP
- CNTRL/K - Return to Source Screen

RESUME PREVIOUS SESSION

The user is asked to enter the filename of the previous session. This is the same filename entered at the conclusion of the initial session. All filenames are given the same extension (.SLG) by the system. The SOURCE and TEST ID are obtained from the previous session log.

STEP 2: SELECT RETRIEVAL OPTION

After program initialization has identified the SOURCE and TEST ID, the user will have the following options available:

DATA RETRIEVAL MAIN MENU

- (A) - Select a Data Label
- (B) - Select a Data Set
- (C) - List Data Labels Selected
- (D) - List Data Sets Selected
- (E) - Generate a Report of Data Selected
- (F) - Save Session Log and Exit
- (G) - Build RS/1 Input File
- (?) - HELP
- CNTRL/K - Exit Data Retrieval Program

When used by a Test Engineer or the Database Manager, an additional Option (H) is available for loading reduced data into the engineering data files. But this option is not available to the analysis user.

STEP 3: SELECT LABELS

In the example, it is assumed that the user wants all RUN and RERUN values to be the first 2 columns of the resulting RS/1 Table. Since the data will appear in the order selected, the user will enter these labels first by selecting "A" to choose these labels. This presents the options:

- (A) - View and Choose a Label
- (B) - Enter a Label

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The first option allows scrolling through the list of labels defined for the test to make a selection, while the second option prompts entry of the label name. In either case, once a label has been identified, the user is prompted for a value range. In the example, the user does not desire to restrict the data based on RUN or RERUN, so no range is entered (only a carriage return).

Since the values for the label FLOW must be limited, the range 450 to 455 is entered. This limits the range of runs to 100 through 102 excluding RUN 102 RERUN 4.

This ends the label selection for the example, but label selection can be extended after set selection if desired.

STEP 4: SELECT SETS

In the example, it is assumed that the user wants pressures associated with sets PLANE H and LINE A, so the user selects "B" from the data retrieval main menu. This presents the options:

- (A) - View and Choose a Set
- (B) - Enter a Set

The first option allows scrolling through the list of sets to make a selection, while the second option prompts entry of the set name. In either case, once the set has been identified, data for all labels in the set are selected for the range of run conditions currently established.

For the example, the set names PLANE H and LINE A are selected. This ends the set selection for the example, but set selection can be reentered to extended selections if desired.

STEP 5: PREPARE OUTPUT

After making the desired label and set selections, the user has the option of selecting an output form(s) or exiting as described in Step 6. Two output options are available: preparing a report of the data in an output file for printing, or building metafiles for loading into RS/1 tables.

GENERATE A REPORT OF DATA SELECTED

This option formats a file for printing a report in a 132 column mode. The file is arranged with rows representing the labels selected and columns representing the run conditions. The report is output on file FOR003.DAT.

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BUILD RS/1 INPUT FILE

With this option the user will be prompted for a file name of up to ten characters. The filename must not include a file extension.

Enter RS/1 File Name : EXAMPLE_____

The filenames created by the system are :

- EXAMPLE.RS11 - Data VALUE table file.
- EXAMPLE.RS12 - SET plotting parameters table file. This file is created only if the user selected sets in the retrieval process.
- EXAMPLE.RS13 - LABEL description table file. This file contains all data in the file records for the selected Labels. This will include a label descriptor.

The tables resulting from the example session are illustrated in Table 2.4. It is intended that a RS/1 procedure will be used to combine files .RS11 and .RS12 to produce the combined table shown in Table 2.4 with the plotting values aligned in the same columns as the corresponding labels. Note that P1 is a member of both sets, so it is entered twice.

STEP 6: EXIT THE SESSION

At any time, the user has the option of selecting a termination mode. Two termination options are available: save the session log and exit, or quit without saving any output.

SAVE THE SESSION LOG

This option allows the user to create a session log file containing pointers to the data selected. The session may be resumed at a later time by selecting the "Resume Previous Session" option at initialization.

The user is requested to enter a session name of up to ten characters without a filename extension.

Enter session name : EXAMPLE_____

The system will add the extension to obtain EXAMPLE.SLG.

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Selection of this option will terminate the Data Retrieval Task after the session log has been created.

CNTRL/K (QUIT)

This option returns to the main menu without saving a session log. This should be taken if errors have been made in the retrieval and a restart is desired, or if the desired output form has been obtained and no re-entry to add data is expected.

EXAMPLE OUTPUT FILES FOR RS/1 TABLES

13

3.0 DATA ENTRY

Data from three MSFC Water-Flow Facility (WFF) tests were entered into measured database files and one of these was converted to engineering database files. An additional test from the MSFC Transonic Wind Tunnel (TWT 705) was loaded; but errors were found in the data, so the files were discarded. These data were corrected, but they were not loaded as a part of this contract.

Measurements from a Rocketdyne SSME model test were also considered for entry. These data were only available as time records of the full test duration, so that data reduction as well as data entry were required. It was decided that the task was not within the scope of this work and may not be economically justified under any circumstance.

Measured data were loaded for tests WFF 0017, WFF 0022, and WFF 0023, and engineering data were derived for test WFF 0023. These were all water-flow tests of half-scale models of the hydrogen turbopump hot-gas manifold. In all cases, the data were available in card image form as pressure coefficients. FORTRAN code modules were written to convert the data from the card image format to the current standard database entry form. The data were then read into the database in the original pressure coefficient form.

Data from test WFF 0023 was the most comprehensive and meaningful of the three tests, so these data were condensed, reformatted, and entered into engineering database files. The test is described in Ref. 5 and the procedures used in processing the data to obtain the engineering files are described in Ref. 6.

In test WFF 0023, the number of pressure measurements per run was limited to 37, so 738 run/rerun conditions were used to acquire data for 371 runs representing four hardware configurations and seven instrument patterns. The results provide data at the 489 pressure measurement locations. The instruments were generally installed in circular patterns corresponding to planes through the flow passages in the 1/2 scale model of the SSME hydrogen hot-gas manifold.

Because of the small amount of data taken on each run, the measured database files were sparsely populated. The purpose in forming the engineering database files was to compress the information content of the data to ease user access and minimize storage requirements. The final form desired represented a table with about 500 columns representing each measurement position with rows representing each of the four configurations tested. Three rows of data were used to describe measurements for each configuration. The three rows represented the mean value of the measurements at the location, the standard deviation from the mean, and the number of data samples used in the statistics. In some locations, such as pressure traverses, only one data value

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was available for a measurement location; in other locations, measurements were made on many runs.

A production-line procedure was used to perform the data reduction since all the measured data were available. The tasks which were performed in generating the engineering database and loading it were:

1. Retrieve measured data from the database for each model configuration.
2. Move the measured data into an RS/1 measured value table for each configuration.
3. Reformat the data into a table corresponding to the data labels for the engineering data. This included conversion from pressure coefficient to pressure in psi.
4. Select an appropriate rerun or use all reruns for a run condition (using criteria in Ref. 5), and perform the statistical analysis on the resulting data.
5. Move the statistical data from the table for each of the configurations to the final engineering data table for transfer into the database.
6. Generate table_RS12 and table_RS13 to describe data set descriptions and labels corresponding to the engineering data model.
7. Move the data tables into metafiles and load the metafiles into the database engineering files.

The data conversion and processing in Steps 3 and 4 above were performed using RS/1 procedures.

Although interactive task times depend on the system load, the database system generally performed all tasks in acceptable times. Most tasks in generating and loading metafiles took less than 5 minutes, and preparing printed reports on all data for a configuration took about 5 minutes.

Operations in the RS1 system were quite slow because of the large tables operated on, but this handicap was circumvented to some extent by running these operations as batch jobs at night. Loading data from the database-generated metafiles into a table took on the order of 1 hour of CPU time, and operation of the procedures used to perform Steps 3 and 4 above took less than 1 hour of CPU time each exclusive of the column inserts required to reformat the data from the measured to engineering table format. Column inserts in these large tables was consistently slow. In one instance, it was necessary to insert 12 columns into a 209 x 503 table in the vicinity of column 150. This operation required

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2 hours 37 minutes of CPU time.

The times for transfer of the data from the database to the RS/1 tables will be significantly reduced by future enhancements which will use the Host Language Interface and other RS/1 improvements. It is anticipated that improvements to the RS/1 system will also improve its speed in manipulating tables, and if large table manipulations are required, procedures can easily be written to perform them in batch mode.

4.0 DATA ANALYSIS

Data analysis products from this contract included an evaluation of SSME data analysis methods (Ref. 7) and a recommendation of geometry conventions and transformation procedures (Ref. 1). Work in these two areas is summarized below.

4.1 SSME DATA ANALYSIS METHODS

The two issues addressed in data analysis methods were methods of measuring losses in ducts and considerations in scaling SSME data from water and air flow tests.

Evaluation of Loss Measurements

The flow leaving the turbine on the SSME to proceed through the turn-around duct and the transfer ducts to the combustion chamber is very complex. In the actual engine, the flow has a swirl component, density inhomogeneities, and is periodically unsteady. As a result, no single flow property measurement can be made to characterize the flow, and a method is desired to use a number of measurements to form appropriate averages to characterize the flow.

The equations examined in the evaluation included continuity, momentum, energy, kinetic energy, and entropy. After many simplifying assumptions, including constant density, a measure of the stagnation pressure was derived. The stagnation pressure defined for loss measurements at the entrance or exit area of a control volume was derived to be

$$\overline{p_0} = \frac{\int_s p (\vec{u} \cdot \hat{n}) dA}{\int_s (\vec{u} \cdot \hat{n}) dA} + \frac{1}{2} \rho \frac{\int_s u^2 (\vec{u} \cdot \hat{n}) dA}{\int_s (\vec{u} \cdot \hat{n}) dA}$$

where: $\overline{p_0}$ = average stagnation pressure
 p = static pressure
 \vec{u} = velocity vector
 \hat{n} = unit normal to control volume entrance/exit area
 A = area
 ρ = fluid density

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This can be written as a summation over incremental areas as

$$\overline{p_o} = \frac{\sum p_{oi} \text{ uni } A_i}{\sum \text{ uni } A_i}$$

where: $\overline{p_o}$ = average stagnation pressure
 p_{oi} = stagnation pressure for area increment i
 uni = component of velocity normal to A_i
 A_i = control volume entrance/exit incremental area

The analysis indicated that the measurement of stagnation pressure loss is a useful measure of the effectiveness of modifications to engine geometry. But two problems exist with the present techniques. The correct average given by the equations above requires the measurement of the component of velocity normal to the control volume. This can be measured with 3-D probes, but not with Kiel probes or standard pitot probes. However, 3-D probes may not be useful since they are greatly influenced by free stream turbulence and swirl. The problem of swirl and vortices introduces considerations which have not been fully addressed in the current measurements. Time-dependent behavior has been shown to exist in the flow in the hot-gas manifold, and this behavior needs to be examined to determine if a meaningful time average is being measured.

Scaling Considerations

Measurements are being made on scale models of the SSME using both air and water as the fluid media. These measurements must then be "scaled" so that they will apply to the full-scale engine, but scaling can only be performed after the functional relationships between the dependent and independent non-dimensional parameters are known. These functional relationships are not presently known because of the paucity of SSME model and full-scale data, so scaling cannot be performed.

A careful dimensional analysis indicates that the important quantities in determining a parameter such as hot-gas manifold pressure loss are not known. Therefore, predictions of full-scale performance will require matching of all non-dimensional parameters between model and full-scale. However, this approach has the difficulty that the full-scale flow is so complex that not all the important functional parameters are known.

Water flow simulation of compressible flows has been found to be useful in visualizing unsteady vortical phenomena and flow separations, but it is not generally applicable to more

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quantative measurements such as evaluation of losses in the hot-gas manifold. However, because of the very high pressures in the SSME, Reynolds number is a better match between full-scale and water-flow model conditions than for most aerodynamic testing.

Air-flow testing can be expected to give a reasonable simulation of the full-scale engine if Reynolds and Mach numbers can be matched and the inlet conditions can be reasonably well modeled. However, the hot-gas manifold inlet conditions on the full-scale SSME are complex and difficult to characterize through full-scale measurements.

Additional testing is required in order to gain an improved understanding of the flow in the hot gas manifold so that useful extrapolation to full-scale can be performed. These experiments should be carried out in both air and water as test media, and geometry, Reynolds number, inlet flow, etc. should be varied over as wide a range as possible before attempts are made to apply these model experimental results. Knowledge gained from such experiments is expected to allow predicitions of geometric modifications which can lead to improvements in engine performance.

Since geometry is so important in the hot-gas manifold flow uniformity, consideration should be given to developing variable geometry models. This concept is obviously difficult, but the benefits to be gained in improving performance with a minimum of testing are so great that it should not be dismissed. Taking large amounts of data on non-optimum configurations does little to advance improvements in SSME performance.

4.2 GEOMETRY CONVENTIONS

A standard geometry description procedure for test articles is required for database operation and desirable for consistency in other aspects of testing. The procedure is expected to:

1. Provide a standard method of describing coordinate axes.
2. Provide a guide for assigning axis directions for components under test.
3. Provide a standard method of specifying transformation parameters required to relate coordinate systems for separate components.

Such a procedure is proposed in Ref. 1, but it had not been approved as of the end of the contract. This work will continue in the future, and database structures will be designed to store and access the data. Some of the features of the current

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proposed standard are described below.

The proposed system design defaults to a right-hand Cartesian coordinate system for component geometry with rotations measured positive in the right-hand sense. However, provisions are planned to identify either a left-hand Cartesian system or a cylindrical system. The system also provides for defining cylindrical systems about any of the axes of a Cartesian system with a right- or left-hand rotation angle originating at either of the two remaining axes.

A recommended procedure is provided to align axes with flow in a component or system in order to provide a uniformity of understanding, but the database structure is not dependent on this. It is proposed that the X-axis align with the flow direction at the entrance of a component. In order to minimize negative values, a nominal reference value (e.g. X=100) should be assigned to a significant feature of the component (e.g. an interface flange). The Z-axis should be aligned so that the XZ-plane represents a plane of symmetry for the component if one exists. The Y-axis direction is then in the direction consistent with the coordinate system being used.

A structure is proposed to orient each local coordinate system in a higher-level reference system. The reference system can, in turn, be described as a local system in the next level reference system. This is similar to a tree-type structure with a root node representing the highest level system relating the component geometries. By composing transformation matrices from the coordinate system parameters used, it is possible for a database routine to reference any component in the coordinates of any other component or higher-level system. Initially, the referencing could be output listings of corresponding locations, but eventually it is planned to provide display of the component geometries in a selected system.

In an example related to the SSME, the root node of the tree-type structure relating coordinate systems could be the entire engine with the X-axis along the nozzle centerline and station 100 at the gimbal point. This could be followed by coordinate systems representing components such as the hot-gas manifold, the hydrogen turbine housing, the hydrogen-side transfer ducts, etc. Components in these major sub-systems would be represented at the next level, and at the lowest level would be instrument locations in the components (e.g. the left transfer duct). Each of these instrument locations could be represented in the coordinate system represented by the component in which it is mounted, or transformed to another component (e.g. the turn-around duct) for direct geometric comparison with other instrument locations in that component.